Cardiothoracic Anesthesia: Current Controversies

A. Zwerling, DNP, CRNA, DAAPM
a.to.z@comcast.net  NDANA 10-23-09
Focus of Today’s Lecture
Regulation of Na+/K+-ATPase activity by nitric oxide in the kidney and gill of the brown trout (Salmo trutta)

Christian K. Tipsmark and Steffen S. Madsen

doi: 10.1242/jeb.00284
Comparative Physiology
Stress elevates corticotropin-releasing factor (CRF) and CRF-binding protein mRNA levels in rainbow trout

C Doyon, V L Trudeau and T W Moon

Journal of Endocrinology (2005) 186, 123-130
Take Homes

- Appropriate patient selection
- Beta 1 Blockade
- Alpha 2 Blockade
- Fast Track
- Anesthetic Preconditioning
- Levoisomedan
- Portland Protocol (tight glycemic control)
Brief Historical Overview

• For those of us who have witnessed the evolution of ventricular assist devices!

“The docs just install the artificial heart. We at Al's garage do the maintenance.”
Heart-lung machine, Model II, “the size and shape of a spinet piano,”
1951
Dr. Gibbon and former patient Cecelia Bavolek pose before the Plexiglas covered “lung” 10 years after in 1963.
First Pump Oxygenator
Mayo Clinic 1953
The 1957 Lillehei/Dewall cardiopulmonary bypass machine, as assembled by Cliff Lambourne and first used for removal of an atrial myxoma on February 26th 1957 at the Northern General Hospital (then known as the City General Hospital). This is believed to be only the second bypass operation performed outside the USA.
Minimally Invasive MVR
Ready for Aortic Cannulation
And the TEE Says.......
A friend of mine once sent me a post card with a picture of the entire planet Earth taken from space. On the back it said, "Wish you were here."

Steven Wright
Topics

• Cardiac Induction
• Choice of Anesthetic Agents
• Pre-Bypass Period
• Cardioprotective Strategies
• Anticoagulation
• Bleeding Prophylaxis
• Cannulation
• Bypass Period
• Cerebral Protection
Controversies

• Thrombotic events with antifibrinolytics
• Beta blockade
• Alpha 2 agonists
• PA catheter utilization
• Fast tracking
• Off pump CABG
Cardiac Induction

• Anesthetic goals: Analgesia, amnesia, muscle relaxation. Also, abolition of autonomic reflexes, maintaining physiologic homeostasis, provide myocardial and cerebral protection.

• Balanced technique with opioid, inhalation agents, sedative-hypnotics, muscle relaxant
  – Provides stable hemodynamic state for difficult CV pt.
Cardiac Induction

- Dose requirements inversely related to ventricular function
- Severely compromised patients should receive agents slowly and in small increments
Induction, cont.

Propofol, Fentanyl induction commonly used. After loss of consciousness, Pancuronium generally given.

- Cardiac 10-20cc Fentanyl up front
  - M&M recommends 15-40mcg/kg for induction and intubation, maintenance with 3-5mcg/kg PRN
  - Total Fentanyl dose about 50-100mcg/kg
Induction, cont.

- Pancuronium best choice for the reason that its vagolytic effects offset opioid–induced bradycardia.
- Etomidate used for patients with EF <40
- VIA slowly increased and carefully titrates to blood pressure. Isoflurane most commonly used. N2O commonly not used due to intravascular bubblesthat may form during CPB.
Preconditioning with sevoflurane: Recent data

• Isolated heart model
  – Inhaled sevoflurane administered before or after ischemic insult

• Sevoflurane improves post-ischemic cardiac function while reducing Ca\(^{2+}\) loading when administered before or after ischemia
  – Protection is better when sevoflurane is administered before ischemia
  – Reduced Ca\(^{2+}\) loading on reperfusion likely a result of anesthetic protective effect

Srinivasan G et al, Anesthesiology 2002;96:125-33
“Minimally Invasive” Cardiac Surgery (MIDCAB)

- Growth in cases that do not require CPB
  - “Politically correct” cardiac surgery
  - Technique initially limited, but expanding
- Shorter hospital stay, recovery
- Surgical techniques changing rapidly
  - Anesthesia strategies will follow
  - Extubation on the table is desirable
If you shoot at mimes, should you use a silencer?  
Steven Wright
myocardial contractility
Sevoflurane but Not Propofol Preserves Myocardial Function in Coronary Surgery Patients

Stefan G. De Hert, M.D., Ph. D., Pieter W. ten Broecke, M.D. Els Merten, M.D., Esther W. Van Sommeren, M.D., Ivo G. De Blier, M.D., Bernard A Stockman, M.D., Inez E. Rodrigus, M.D.
Anesthesiology 97:42-49, 2002

![Graphs showing troponin I levels with ICU time (hours) for Propofol and Sevoflurane.]
Pre-Bypass Period

- Following induction and intubation, the anesthetic course is typically characterized by a period of minimal stimulation (skin prep, etc) that is frequently associated with hypotension, followed by discrete periods of intense stimulation that can produce tachycardia and hypertension.
- Anesthetic agent is used to adjust appropriately in anticipation of events.
Pre-Bypass Period

- Vagal response may occur during sternal retraction or opening of the pericardium.
- Deeply anesthetized patients frequently have progressive decline in COP after chest opening. May be due to decreased venous return as the normally negative intrathoracic pressure becomes atmospheric.
Anticoagulation

- Must be established prior to CPB to prevent acute disseminated intravascular coagulation (DIC) and clot formation in CPB pump.
- Adequacy of anticoagulation therapy confirmed by ACT
  - Unit of measurement is time in seconds to detect formation of blood clot in a 2-3mL sample
  - Longer than 400-450 seconds
  - Normal ACT 130 seconds (Valley says 70-
Anticoagulation cont.

- ACT prolonged by hypothermia and hemodilution.
- ACT Activators
  - Celite
  - Kaolin
- With Aprotinin
  - Celite ACT >750 seconds
  - Kaolin ACT >400 seconds
- When Aprotinin is used, A Kaolin ACT rather than Celite ACT should be used to guide heparin therapy.
Heparin

- Heparin 300-400 U/kg given, usually while aortic purse string sutures are placed during cannulation.
  - On Heparin, 400; Off Heparin, 300
  - At Cooper 400U/kg standard
- Catalyst that binds with circulation antithrombin (AT III) and potentiates its natural anticoagulant properties.
Heparin

- Administered IV through CVP, some surgeons may prefer to give into RA themselves.
- Peak effect within 2 minutes, verification based on ACT, established 5-10 minutes after administration.
Heparization

• Loading dose may be altered depending on special circumstances:
  – Long-term heparinization, AT III deficiency, heparin-induced thrombocytopenia, excessive hemodilution which may cause “heparin resistance”

• Anti-thrombin III is a circulating serine protease that irreversibly binds and inactivates thrombin, as well as activated forms of factors X, XI, XII, and XIII.
Heparization

• AT III’s anticoagulant activity is enhanced 1000-fold with heparin administration.
Heparinization, cont.

• Question: A patient about to go under coronary artery bypass graft surgery is unresponsive to heparin (ACT does not increase). What is the most likely reason the patient is unresponsive to heparin? What action should be taken to correct this unresponsiveness?
  – **AT III deficiency**
  – **2 units of FFP** generally results in adequate anticoagulation (AT III is
Heparin Alternatives

- Heparin Alternatives
  - Heparin-Like Alternatives
    - Low Molecular Weight Heparins
    - Heparinoids (dermatan sulfate; danaparoid)
  - Hirudin
    - Leech salivary gland
    - Renal clearance
    - ECT
  - Bivalirudin
    - Synthetic thrombin inhibitor
    - Renal clearance
  - Argatroban
    - Direct thrombin inhibitor
  - Ancrod
    - Extract of viper venom
    - Lyses fibrinogen
Bleeding Prophylaxis

- Antifibrinolytic agents
  - reduce peri-operative bleeding

- Amicar (Aminocaproic Acid)
  - Lysine analogue
  - The fibrinolysis-inhibitory effects of AMICAR appear to be exerted principally via inhibition of plasminogen activators and to a lesser degree through antiplasmin activity.
  - For the treatment of acute bleeding syndromes due to elevated fibrinolytic activity, it is suggested that 16 to 20 mL (4 to 5 g) of AMICAR Injection in 250 mL of diluent be administered by infusion during the first hour of treatment, followed by a continuing infusion at the rate of 4 mL (1 g) per hour in 50 mL of diluent.
  - Does not affect ACT
  - Unlikely to cause allergic reaction; **NO test dose needed**
Aprotinin: FYI

- Broad spectrum protease inhibitor which modulates the systemic inflammatory response (SIR) associated with cardiopulmonary bypass (CPB) surgery. SIR results in the interrelated activation of the hemostatic, fibrinolytic, cellular and humoral inflammatory systems. Aprotinin, inhibits of multiple mediators [e.g., kallikrein, plasmin] results in the attenuation of inflammatory responses, fibrinolysis, and thrombin generation.
Aprotinin: FYI

- Aprotinin inhibits pro-inflammatory cytokine release and maintains glycoprotein homeostasis. In platelets, aprotinin reduces glycoprotein loss (e.g., GpIb, GpIIb/IIIa), while in granulocytes it prevents the expression of pro-inflammatory adhesive glycoproteins (e.g., CD11b).

- The effects of aprotinin use in CPB involves a reduction in inflammatory response which translates into a decreased need for allogeneic blood transfusions, reduced bleeding, and decreased mediastinal re-exploration for bleeding.
Aprotinin

- Considered for patients undergoing repeat operation, those who refuse blood products (JW), those at high risk for post-op bleeding, and complicated cases involving heart and aorta.
- Reduces blood loss and transfusion requirements by 40-80%
- Serious allergic reactions, including anaphylaxis, esp. with multiple exposure.
  - **Test dose** given prior to loading dose
  - Loading dose given, then infusion throughout surgery
Aprotinin

- Given after induction but before sternotomy, allergic reaction
- Always check with surgeon
Sponges grow in the ocean. That just kills me. I wonder how much deeper the ocean would be if that didn't happen.

Steven Wright
Fast-Track Cardiac Anesthesia: Choice of Anesthetic Agents and Techniques

Paul S. Myles, MBBS, MPH, MD, and David McIlroy, MBBS

Seminars in Cardiothoracic and Vascular Anesthesia, Vol. 9, No. 1, 5-16 (2005)
Fast Track Strategies

- Chong and colleagues used a balanced volatile and low-dose fentanyl (10–15 μg/kg) technique in their experience with early extubation and establishment of a cardiac recovery area.
- Bell and colleagues compared propofol (4–8 mg • kg−1 • hr−1) and low-dose fentanyl (15 μg/kg) with a high-dose fentanyl (60 μg/kg) technique in 39 patients with poor ventricular function and demonstrated earlier extubation and ICU discharge, with similar hemodynamic changes throughout.
- Myles and colleagues compared a similar propofol low-dose fentanyl technique with enflurane, and moderate-dose fentanyl (30 μg/kg) in a broad range of patients. They found a reduction in median extubation times from 12 hours to 9 hours.
Fast Track Strategies

• Cheng and colleagues used an isoflurane and low-dose fentanyl (15 μg/kg)-based technique, followed by propofol sedation in the ICU, that allowed tracheal extubation in most patients within 6 hours of surgery. They found a 25% reduction in total healthcare costs with no demonstrable increase in postoperative complications.

• Silbert and colleagues used a similar propofol low-dose fentanyl technique to achieve a marked reduction in time to tracheal extubation, from 7 hours to 4 hours when compared with fentanyl (50 μg/kg).
Neroprotection & Cardioprotective Slides

A Practical Approach to Cardiac Anesthesia, 3rd edition
Edited by Frederick A. Hensley, Jr., M.D., Donald E. Martin, M.D., Glenn P. Gravlee, M.D.
Published: 31 December, 2002
ISBN: 0781734444
Relationship between myocardial oxygen supply (DPTI, diastolic pressure time index) and myocardial oxygen demands (TTI, tension time index) during the Cardiac cycle. Left atrial or pulmonary artery wedge pressure tracings and aortic blood pressure tracings can be used to estimate these indexes clinically. (From Buckberg GD. Recent progress in myocardial protection during cardiac operations. In: McGoon DC, ed. Cardiac surgery, 2nd ed. Philadelphia: FA Davis Co, 1987:291, with permission.)
Changes in myocardial oxygen consumption in mL/100 g/minute relative to myocardial work condition and myocardial temperature. Myocardial oxygen consumption decreases linearly as temperature is reduced. At any specific myocardial temperature, inducing myocardial arrest markedly decreases oxygen consumption. (From Buckberg GD. Recent progress in myocardial protection during cardiac operations. In: McGoon DC, ed. Cardiac surgery, 2nd ed. Philadelphia: FA Davis Co, 1987:291, with permission.)
Myocardial anaerobic metabolism. On the left is the glycolytic pathway, whereby endogenous glycogen or exogenously supplied glucose is metabolized to pyruvate yielding two moles of adenosine 5'-triphosphate (ADP) for each mole of glucose consumed. Pyruvate can be further metabolized to lactate during anaerobic conditions. Alternatively, pyruvate can be transamminated with glutamate, yielding α-ketoglutarate, which can enter the mitochondria and yield an additional mole of ATP anaerobically. On the right is the pathway for anaerobic amino acid metabolism, whereby aspartate can be deaminated with α-ketoglutarate, yielding malate, which can enter the mitochondria and yield an additional mole of ATP in the absence of oxygen. Note that these pathways also regenerate nicotinamide adenine dinucleotide, which helps sustain continued anaerobic glycolysis.
Cardioplegia Strategies

Effects of cardioplegic induction temperature and amino acid enrichment on postischemic recovery in energy-depleted hearts. Note the near-complete functional recovery achieved by the combination of warm (37°C) cardioplegic induction temperature and amino acid enrichment of the blood cardioplegia solution.
Sources of neuronal injury from cardiopulmonary bypass. IEGs, immediate-early genes; nNOS, neuronal nitric oxide synthase; eNOS, endothelial nitric oxide synthase.
During CPB
Cardioprotective Properties of Sevoflurane in Patients Undergoing Coronary Surgery with Cardiopulmonary Bypass Are Related to the Modalities of it’s Administration

De Hert, Stefan G. M.D., Ph.D.; Van der Linden, Philippe J. M.D., Ph.D.; Cromheecke, Stefanie M.D.; Meeus, Roel M.D.§; Nelis, Anne M.D.; Van Reeth, Veronique M.D.; ten Broecke, Pieter W. M.D.; De Blier, Ivo G. M.D; Stockman, Bernard A. M.D; Rodrigus, Inez E. M.D., Ph.D.

Anesthesiology: Volume 101(2) August 2004 pp 299-310
Results

• Conclusion: In patients undergoing coronary artery surgery with cardiopulmonary bypass, the cardioprotective effects of sevoflurane were clinically most apparent when it was administered throughout the operation.
Anesthetic preconditioning: triggering role of reactive oxygen and nitrogen species in isolated hearts

Enis Novalija, et. al
Results

- postulated that anesthetic preconditioning (APC) is triggered by reactive oxygen/nitrogen species (ROS/RNS).
- APC (two, 2-min periods of perfusion with 0.32 ± 0.02 mM of sevoflurane; separated by a 6-min period of perfusion without sevoflurane)
- Thus APC is initiated by ROS as shown by improved function, reduced infarct size, and reduced dityrosine on reperfusion; protective and ROS/RNS-reducing effect of APC were attenuated when bracketed by ROS scavengers or NO· inhibition.
During CPB
Incision to Bypass

- Skin incision and sternal split extremely stimulating.
  - Pt. should show minimal response
  - Continuous opioid infusion, deepen VIA
  - Maintain BP, Consider Nitroglycerin for smooth CPB transition.
    - Lungs deflated with sternotomy to prevent puncture.

- Cannulation
  - Reduction of MAP assist aortic cannulation and prevents laceration of aorta.
  - Venous cannulation (RA): fluctuations in arterial pressure, ventricular dysrhythmias, decreased COP.
  - See “Checklist for going on pump”
Aortic Cannulation

- Cannulation site
- Ascending aorta
- Ductus arteriosus
- Innominate artery
- Left common carotid artery
- Left subclavian artery
- Rubber shod
- Purse string suture
- Incision
- Aortic cannula
- Pulled purse string
- Pulled rubber shod
- Cannulation clamp
Bypass Period

• Systemic arterial pressure closely monitored as pump flow is gradually increased to 2-2.5C/min/m²
Bypass Period

• Abrupt hypotension related to abrupt hemodilution which markedly reduces SVR.
  – MAP = Pump flow x SVR
  – Thus at a constant SVR, MAP is proportional to pump flow
  – MAP 50-80mmHG
  – Flow requirements proportional to core temp.
    • Deep hypothermia with MAP at 30-40mmHg may still provide adequate CBF.
  – Increased SVR with Phenylephrine.
Bypass cont.

- HTN exist with MAP >100mmHg, increasing risk for aortic dissection or cerebral hemorrhage.
  - Treat by:
    - decreasing pump flow
    - adding Iso to oxygenator inflow gas
    - Consider Nitroglycerin.
- In the absence of hypoxemia, low venous oxygen sat. (<70%), a progressive metabolic acidosis, or low urinary output are indicative of inadequate flow rates.
In a Nutshell

**Perfusion**
- CPB flows for CI > 2.0 l/mim/sqaure meter
- MAP within 25% of baseline: (60 – 80) mmHg
- Maintain SVR with titrated phenylephrine
- Cardioplegia PSR

**Metabolic Milieu**
- ABG Q30 minutes
- ACT immediately after bypass, then q20-30minutes
  - Cooling generally increases heparin half-life
- Keep HCT 20-25%
- Glucose (100 –150)mg/dL
- Serum K (4-5) mmol/L, Treated with Lasix
- Adjust oxygenator for 02/C02

**Anesthetic Technique**
- Inhalational Agent
- Neuromuscular blocker
- Opioid
- **Mannitol**
  - Osmotic diuretic
  - Free radical scavenger
  - 12.5 g – 25 g in CPB prime
  - May be renally protective

- **Furosemide**
  - Loop diuretic
  - 10 – 200 mg IV bolus
  - Caution in sulfonamide allergy

- **Fenoldopam**
  - Dopamine 1 agonist
  - Selective arterial vasodilator
  - Increases renal blood flow (may be protective)
  - Infusion 0.1 – 0.5 mcg/kg/min
  - Fast onset/ Offset within 60 minutes
Hypothermia

• Moderate (26-32°C) or Deep (20-25°C) used routinely
  – Lower temps allow decreased pump flows
• VF occurs at 28-29°C, then immediate cardioplegia
Cardioplegia

- Potassium solution administered into coronary circulation, provides diastolic arrest.
  - Composed of K (15-30mEq/L), Ca (to prevent ischemic contracture, stone heart), Albumin or Mannitol for osmolarity correction, and glucose as a metabolic substrate.
- Compostition is blood or crystalloid based.
  - Blood based is oxygenated blood that is diluted with fluid at a 4:1 ratio. HCT of 16-18%, given at 4-14°C.
  - Crystalloid based solutions do not contain Hb, thus deliver dissolved O2 only.
- Administration
  - Antegrade into aortic root below cross clamp, from which it distributes to coronaries and into myocardium.
  - Retrograde into coronary sinus, from which distributes through veins, vessels, and capillaries of myocardium.
Cerebral Protection

- Neurologic complications following CPB may be as high as 40%, most serious complications i.e., stroke occur in 2-5%.
- Factors associated with neurologic sequelae include: valvular procedures, advanced age, preexisting cerebrovascular disease.
Cerebral Protection

• Preexisting CV disease, maintain higher perfusion pressures during CPB
• Embolic phenomena seem responsible for most neurological defects
  – Emboli sources include aortic atheroma from aortic clamp, intraventricular thrombi, valve calcification, air during open chamber procedures, bubble oxygenators, N2O before CPB, pump runs longer than 90 minutes.
Cerebral Protection

• At MAP 50-150mmHG (autoregulatory plateau), CBF is maintained at 50ml/100g/min because of changes in vascular tone
• Cerebral autoregulation is dependent on CBF and MAP and is established at a lower plateau with hypothermia
Cerebral Protection

• Changes in ABP and blood flow may precipitate as a result of hypothermic responses, hypocarbia, venous congestion arising from SVC obstruction or emboli.

• Prior to circulatory arrest, deep hypothermia (15-20C)
Cerebral Protection Techniques

• Maintain MAP >50mmHg after start of rewarming
• Maintain euglycemia
  – Hyperglycemia prevents the increase of adenosine, which is responsible for cerebrovasodilatation, preventing brain from protecting itself from ischemic damage
  – Avoid glucose containing solutions
  – Insulin therapy may be needed (DOSE)
• Maintain mild hypothermia
  – Deep hypothermic circ arrest, cool to 15-20°C
• Perform pharmocologic metabolic suppression
  – STP, Propofol, Ca Channel Blockers (decrease vasospasm)
  – Aprotitin (assoc. with decreased stroke incidence)
Voilla!

Before

Blocked coronary artery

After

Vein graft sewn in to bypass blockage
When I was a little kid we had a sand box. It was a quicksand box. I was an only child... eventually.

Steven Wright
References: Fast Track

References


• Silbert BS, Santamaria JD, O'Brien JL, Blyth CM, Kelly WJ, Molnar RR: The fast track cardiac care team: Early extubation following coronary artery bypass surgery: A prospective randomized controlled trial. Chest 1998; 113: 1481-8

References


• Sherry KM, McNamara J, Brown JS, Drummond M: An economic evaluation of propofol/fentanyl compared with midazolam/fentanyl on recovery in the ICU following cardiac surgery. Anaesthesia 1996; 51: 312-7

References


References

References: Pre & Post Conditioning

- Cope DK, Impastato WK, Cohen MV, Downey JM: Volatile anesthetics protect the ischemic rabbit myocardium from infarction. Anesthesiology 1997; 86:699-790
- Zaugg M, Lucchinetti E, Spahn DR, Pasch T, Schaub MC: Volatile anesthetics mimic cardiac preconditioning by priming the activation of mitochondrial KATP channels via multiple signaling pathways. Anesthesiology 2002; 97:4-14
References: Pre & Post Conditioning

- Varadarajan SG, An J, Novalija E, Stowe DF: Sevoflurane before or after ischemia improves contractile and metabolic function while reducing myoplasmic Ca2+ loading in intact hearts. Anesthesiology 2002; 96:125-33
- Obal D, Scharbatke H, Müllenheim J, Preckel B, Schlack W: Myocardial protection by preconditioning with sevoflurane is further enhanced by sevoflurane administration during reperfusion (abstract). Anesthesiology 2002; 97: A-607
References: Pre & Post Conditioning


• De Hert SG, ten Broecke PW, Mertens E, Van Sommeren EW, De Blier IG, Stockman BA, Rodrigus IE: Sevoflurane but not propofol preserves myocardial function in coronary surgery patients. Anesthesiology 2002; 97:42-9
References: Pre & Post Conditioning


• Conzen PF, Fisher S, Detter C, Peter K: Sevoflurane provides greater protection of the myocardium than propofol in patients undergoing off-pump coronary artery bypass surgery. Anesthesiology 2003; 99:826-33

• De Hert SG, Rodrigus IE, Haenen LR, De Mulder PA, Gillebert TC: Recovery of systolic and diastolic left ventricular function early after cardiopulmonary bypass. Anesthesiology 1996; 85:1063-75
References: Pre & Post Conditioning

- Benedict PE, Benedict MB, Su TP, Bolling SF: Opiate drugs and delta-receptor-mediated myocardial protection. Circulation 1999; 100(suppl II):II357-60
- De Hert SG, Van der Linden PJ, Cromheecke S, Meeus R, ten Broecke PW, De Blier IG, Stockman BA, Rodrigus IE: Choice of primary anesthetic regimen can influence intensive care unit length of stay after coronary surgery with cardiopulmonary bypass. Anesthesiology 2004; 101:9-20